COMPUTER PROGRAMS

FOR

HYDROLOGICAL INVESTIGATIONS

Engineering Hydrology Section
Engineering Division
Water Planning and Management Branch
Inland Waters Directorate
Environment Canada

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PREFACE

This computer program summary is intended to provide a ready source of information on the computer programs which could be employed by the Engineering Hydrology Section, or other interested users, in hydrological investigations related to the design of hydraulic structures or comprehensive water planning and management.

To this end the available programs have been grouped together under the following topics; statistical analysis, regression analysis, frequency analysis, duration analysis, backwater calculations, streamflow routing, unit hydrograph techniques, and synthetic streamflow generation. Under each such heading the programs have been summarized, one page per program, in order of importance i.e. the most highly recommended program appears first followed in turn by less highly recommended programs. The recommended usage of every program is presented, and if necessary qualified, in the closing section of each summary. Thus the interested user should have no difficulty in selecting an appropriate program or deciding that a new program has to be developed or acquired from some other agency.

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INTRODUCTION

The responsibility of maintaining a respository for the computer programs of the Water Planning and Management Branch lies with the Engineering and Econometric Systems Section, Water Management Systems Division. However, the Engineering Hydrology Section, Engineering Division is charged with providing expert advice on the use of hydrological programs and developing new or improved methods of hydrologic modelling and analysis. As such this report is intended to (1) provide advice and assistance to scientists and engineers conducting hydrological investigations and (2) provide direction to the modelling and analysis projects of the Engineering Hydrology Section.

In order to meet these dual objectives the summary of each available computer program concentrates on identifying (1) the hydrological technique(s) employed by the program (2) pertinent references to the literature (3) past operational applications of the program (4) the hydrological input required by the program (5) the hydrological output provided and (6) appropriate circumstances for employing the program.

It should be pointed out that one of the more complex modelling and analysis topics has purposely been excluded from this report, namely watershed or rainfall-runoff response modelling. The programs so required are generally larger than those described herein and their data requirements are also an order of magnitude larger because of the need for a meteorological data base. Most of the programs in this report; with the exception of unit hydrograph programs, which are really elementary watershed models, are for the analysis of streamflow records and do not require meteorological input data. The Engineering Hydrology Section is concerned with the use of watershed models such as the SSARR, the STANFORD, the MARMOT and the UBC, etc.; however these will be reported on in separate reports. The direction provided to the modelling and analysis projects of the Section will also be reported elsewhere. This report is restricted to summarizing the many "small" computer programs available to the Section.

The Engineering and Econometric Systems Section also has an extensive file of programs for water resources engineering studies and related socio-economic studies; as well as expertise in linear programming, critical path methods and related topics in systems engineering. Thus the interested reader should contact the above Section for a more extensive computer program summary and for advice regarding comprehensive water resources systems studies.

In addition to the programs which are herein described under the topics of statistical analysis and regression analysis there are many other similar type programs which are available in the program libraries maintained by computer centers (e.g. the BMD library). The interested user should check

these libraries to see if one of their programs is better suited to a particular problem. The programs presented here are those which have been developed specifically for hydrological data sets or have been found useful in past applications.

The intent is that this report will be revised as new programs are developed, old programs improved, and additional programs acquired from other agencies or individuals. Comments, suggestions or reasonably well documented programs for inclusion in future revisions are solicited.

EXPLANATION OF THE PROGRAM SUMMARY

The format of the program summary sheets is explained below under each format heading.

Program Language: Generally Fortran IV.

Computer: The computer for which the available program was written.

Documentation: The extent of the program documentation, restricted to one of three entries:

1. Program documentation (date of same)
2. Program listing with sample output (i.e. no formal documentation is available)
3. Program listing (i.e. no formal documentation is available and and furthermore no sample output is available)

Available From: Generally the programs are available from either the Engineering and Econometric Systems Section or the Engineering Hydrology Section. Computer programs and programming advice should be requested of the Engineering and Econometric Systems Section. Hydrological advice as to the selection of a program can be obtained from the Engineering Hydrology Section.

Author: The name of the programmer, and the Section at the time of programming, if available and if within the Water Planning and Management Branch or its predecessors; or the name of the Section, Division and possibly Branch of Environment Canada at the time of programming; or the name of an outside agency. As such this heading may trace back the development of the program to the roots of current Sections and Divisions within the Water Planning and Management Branch.

Purpose/Technique: A brief statement of the purpose behind the program i.e. the type of analysis being performed, a brief statement of the analysis technique, and possibly some mention of a geographical area for those programs which were written for specific river basins.

References: Pertinent references to publications explaining the analysis technique and to selected Directorate reports involving operational applications of the program.

Past Applications: A listing of past investigations by the Directorate in which the program was utilized.

Input: A concise yet comprehensive listing of the data required by the program. Details being available in the program documentation.

Output: A comprehensive listing of the output. Details being available in the program documentation.

Comments: Generally notes to inform the reader of special features of the program, to mention ongoing development of related techniques, or to support the recommendation which follows.

Recommendation: A recommendation as to the appropriate use of the program, including any necessary qualifications or notes of explaination.

PROGRAM SUMMARIES

STATISTICAL ANALYSIS

A. General

TESTS

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program documentation (April, 1969)

Available From: Engineering and Econometric Systems Section, Water Management Systems Division or Engineering Hydrology Section, Engineering Division

Author: R. Wettlaufer, Saskatchewan - Nelson Basin Board and Engineering Division, Inland Waters Branch

Purpose/Technique: To calculate statistical parameters of monthly data.

Past Applications: Great Lakes Regulation Studies
Saskatchewan - Nelson Basin Study
Fraser River Study

Input: Monthly data

Output: Mean
Standard deviation
Skew coefficient
Serial correlation coefficients
Cross correlation coefficients
Auto correlation coefficients
Spectral analysis coefficients
Hurst's K
Change in quartile
Changes in direction of movement
Frequency

Comments: This program has found widespread use.

Recommendations: The recommended program for a general monthly statistical analysis.

DTEST

Program Language: Fortran IV

Computer: IBM 360

Documentation: Program listing with sample output

Available From: Engineering and Econometric Systems Section, Water Management Systems Division

Author: D.R. Cuthbert, Engineering Systems Section

Purpose/Technique: To calculate statistical parameters of daily data.

Past Applications: Fraser River Study

Input: Daily discharge

Output: Input
Monthly means
Standard deviations of daily data about the monthly means
Average of means and standard deviations as given above
Long term standard deviation of monthly means about long term mean
Long term standard deviation of daily data about long term means and skew of same
Period means (April to September)
Standard deviations of daily flows about period means and skew of same
Long term period mean
Standard deviation of period means about long term mean and skew of same
Autocorrelation coefficients
Changes in direction of movement
Flood frequencies as in program FLDFRQ

Comments: This program was used for a comparison of daily historical and generated data for the Fraser River Study.

Recommendations: The recommended program for a general daily statistical analysis. Elements from program TESTS could be incorporated into DTEST to provide a more comprehensive daily analysis.

DATEST

Program Language: Fortran IV

Computer: IBM 360/85

Documentation: Program listing

Available From: Engineering and Econometric Systems Section, Water Management Systems Division or Engineering Hydrology Division, Engineering Division

Author: D.R. Cuthbert, Engineering Systems Section

Purpose/Technique: Reads ten years of historical daily data at nineteen streamgauge sites and calculates the statistical flow characteristics required for the generation of daily streamflow (program DAGEN, p. 51).

Input: Mean daily discharge

Output: Input
Normalized daily discharges (log base 10)
Standardized daily discharges (by month)
Monthly means and standard deviations of recorded data
Long term monthly means and standard deviations
Regression coefficients

Comments: The statistical parameters required by DAGEN (p. 51) are output on cards.

Recommendations: For use with the daily streamflow generator - DAGEN.

STATAN

Program Language: Fortran IV

Computer: UNIVAC 1108

Documentation: Program documentation (March, 1969)

Available From: Engineering Hydrology Section, Engineering Division

Author: P.N. Gross, Engineering Hydrology Section

Purpose/Technique: Statistical analysis (monthly or daily).

Input: Dependent and independent variables

Output: Means
Variances
Standard deviations
Covariances
Sums of squares
Sums of cross-products of deviations from means
Simple correlation coefficients

Comments: Provides input (on cards) to the regression program REGAN. The two programs combined are referred to as STAREG.

Recommendations: For use with REGAN, which is not the recommended regression program. Programs TESTS and DTEST are the recommended statistical analysis programs.

STATISTICAL ANALYSIS

B. Moving Averages

MEANS

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program documentation (May, 1974)

Available From: Engineering and Econometric Systems Section, Water Management Systems Division or Engineering Hydrology Section, Engineering Division

Author: J.C. Brydges, Engineering and Econometric Systems Section

Purpose/Technique: Calculates the mean discharges of a set of groups of continuous daily flows in a time period of one year or less, i.e. running means for 1, 5, 7 .... days. The program then prints the maximum or minimum 1, 5, 7 .... day mean for the specified time period, as well as its starting date, for each such time period in the input data (e.g. the minimum 5 day mean for each year in a continuous series of 10 years of mean daily discharges).

Past Applications: Low Flow Study

Input: Continuous daily discharges with starting and ending dates

Output: Maximum or minimum 1, 5, 7 .... day means with starting date of the 1, 5, 7 .... day period over a time period of $\leq$ 365 consecutive days for each such time period in the input data.

Comments: Included in the documentation is a description of the procedure used for extracting the required daily flows from the master Water Survey of Canada data files. This program has been used in conjunction with program LOFLOW (p. 22).

Recommendations: The recommended program for searching a data set to locate periods of high and/or low flow.

MOVAV

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program listing with sample output

Available From: Engineering and Econometric Systems Section, Water Management Systems Division

Author: Engineering Division, Inland Waters Branch

Purpose/Technique: Given a series of numbers S_1, S_2, S_3 ... the program calculates 24 sets of arithmetic means

$$\frac{S_1 + S_2 + \ldots + S_n}{n}, \quad \frac{S_2 + S_3 + \ldots + S_{n+1}}{n}, \quad \frac{S_3 + S_4 + \ldots + S_{n+2}}{n}, \ldots$$

where n varies from 1 for the 1st set to 24 for the last set.

Past Applications: Great Lakes Regulation Studies

Input: Data series

Output: Moving averages
Moving averages sorted in descending order

Comments: Although the program is written to calculate 24 sets of moving averages; it could easily be constrained to calculate any one set, or any lesser number of sets.

Recommendations: This is the recommended program for calculating a moving average.

REGRESSION ANALYSIS

A. General

BMD02R

Computer: CDC 6400

Documentation: Program documentation (Biomedical Computer Programs, W.J. Dixon, Editor. University of California Press, Berkley, 1970)

Available From: Energy Mines and Resources, Computer Science Centre

Purpose/Technique: This program computes a sequence of multiple linear regression equations in a stepwise manner. At each step one variable is added to the regression equation. The variable added is the one which makes the greatest reduction in the error sum of squares.

Past Applications: Estimating Storm Runoff Distributions on Ungauged Streams in Nova Scotia. An internal report by R.J. Adamcyk and E. Langley, Engineering Hydrology Section, Water Planning and Operations Branch, Environment Canada, July 1971.

Input: Dependent and independent variables

Output: (1) At each step:
- (a) Multiple R
- (b) Standard error of estimate
- (c) Analysis-of-variance table
- (d) For variables in the equation:
  1. Regression coefficient
  2. Standard error
  3. F to remove
- (e) For variables not in the equation:
  1. Tolerance
  2. Partial correlation coefficient
  3. F to enter

(2) Optional output prior to performing regression:
- (f) Means and standard deviations
- (g) Covariance matrix
- (h) Correlation matrix

(3) Optional output after performing regression:
- (i) List of residuals
- (j) Plots of residuals vs. input variables
- (k) Summary table

Comments: Extensive past applications.

Recommendations: The recommended linear regression program.

BMD05R

Computer: CDC 6400

Documentation: Program documentation (Biomedical Computer Programs, W.J. Dixon, Editor. University of California Press, Berkley, 1970)

Available From: Energy Mines and Resources, Computer Science Centre

Purpose/Technique: This program computes a sequence of K polynomial regressions of the form:

$$Y = \alpha + \beta_1 X + \beta_2 X^2 + ... + \beta_k X^k + e$$

Input: Dependent and independent variables

Output: (1) For data input, after transformation:
- (a) Means
- (b) Correlation coefficients

(2) For each successive degree of polynomial regression:
- (a) Intercept and regression coefficients
- (b) Standard errors of regression coefficients
- (c) Analysis-of-variance table

(3) For the final degree of polynomial regression:
- (a) Analysis-of-variance table
- (b) Table of residuals
- (c) Plot of the observed values and the values predicted from the regression equation

Comments: There are additional regression programs in the BMD (Biomedical) program library.

Recommendations: The recommended polynomial regression program.

REGAN

Program Language: Fortran IV

Computer: UNIVAC 1108

Documentation: Program documentation (March, 1969)

Available From: Engineering Hydrology Section, Engineering Division

Author: P.N. Gross, Engineering Hydrology Section

Purpose/Technique: Stepwise linear multiple regression similar to BMD02R.

Input: Dependent and independent variables plus output from STATAN (see page 5)

Output: For each equation:
Constants
List of the variables
R for each variable
Variance for each variable
Sum of squares
Degrees of freedom
Standard error
Coefficient of determination

Comments: For use with STATAN. The two programs combined are referred to as STAREG.

Recommendations: Program BMD02R is the recommended linear regression program.

DISTOR

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program listing

Available From: Engineering Hydrology Section, Engineering Division

Author: P. Gross, Engineering Hydrology Section

Purpose/Technique: Analyzes and tabulates the results of a regression analysis as performed by REGAN.

Input: Number of independent variables
Number of observations
Values of the dependent and independent variables
Residual sum of squares and sum of squares of the dependent variable
Regression coefficients

Output: Number of independent variables
Number of observations
Regression parameters - coefficient of determination, regression coefficients, standard error of estimate
Table of estimated and observed values of dependent variables, deviations and standard deviations
Analysis of deviations - residual sum of squares, residual mean square, sum of deviations, sum of squares of deviations, mean square of deviations (variance)
Distribution table for standardized deviations - frequency, cumulative frequency
Analysis of regression estimates - coefficient of skew, coefficient of kurtosis
"Student's" t test for observed and estimated values
Analysis of variance - degrees of freedom; independent variables, sum, sum of squares, mean sum of squares; residuals, sum of residuals
F - test

Comments: For use with REGAN, which is not the recommended linear regression program.

Recommendations: BMD02R is the recommended linear regression program.

REGRESSION ANALYSIS

B. Streamflow Correlation

LACOR

Program Language: Fortran II

Computer: IBM 1620

Documentation: Program documentation (November, 1965)

Available From: Engineering and Econometric Systems Section, Water Management Systems Division

Author: R.O'N. Lyons, Water Resources Branch, Departmentof Northern Affairs and National Resources

Purpose/Technique: Correlates two sets of monthly streamflow records using Lanbein's (1960) method, i.e. the correlations are made in terms of deviations in log units from the mean of the logs of each month's discharges.

References: Lyons, R.O'N. Program for Streamflow Correlation. Technical Bulletin No. 2, Water Resources Branch, Department of Northern Affairs and National Resources, November 1965.

Langbein, W.B. 1960. Hydrologic Data Networks and Methods of Extrapolating or Extending Available Hydrologic Data. Hydrologic Networks and Methods, W.M.O., Flood Control Series No. 15.

Input: Monthly mean discharges at the dependent and independent stations

Output: Deviations from monthly mean logs
Correlation coefficients for the simple regression $y = ax + b$
Slope, intercept, coefficient of correlation, standard error of estimate, standard deviation of the dependent variable
Monthly mean logs for the dependent and independent stations
Total of the deviations from the monthly mean logs for the dependent and independent variables

Comments: Simular results could be obtained using program BMD02R.

Recommendations: Program BMD02R is the recommended linear regression equation.

CORREL

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program listing

Available From: Engineering Hydrology Section, Engineering Division

Author: Engineering Hydrology Section, Engineering Division

Purpose/Technique: To estimate water levels on the Ottawa River at Westmeath from those at Fort Coulonge using the linear regression $y = ax + b$.

Input: Daily water levels

Output: Input data
Estimated data
Differences between input and estimated data
Constants for the equation
Standard deviation, standard error and coefficient of correlation
Plot illustrating the relationship between the variables

Comments: Program BMD02R can be constrained to this simple case.

Recommendation: Program BMD02R is the recommended linear regression program.

FLOOD FREQUENCY ANALYSIS

FRQAN

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program listing with sample output

Available From: Engineering Hydrology Section, Engineering Division

Author: R. Kallio, Engineering Hydrology Section

Purpose/Technique: The method of maximum likelihood is used to estimate flood frequencies using the Gumbel I distribution. Also the method of moments is used to estimate parameters and a frequency factor method is used to estimate flood frequencies using the Pearson III, Log-Pearson III and Log-Normal distributions. For the 3-Parameter Lognormal distribution, the lower boundary is estimated by the median method (Sangal and Biswas, 1970) and frequency estimates are obtained using frequency factors.

References: Panchang, G.M., "Improved Precision of Future High Floods", paper presented at the International Symposium on Floods and their Computation, Leningrad, U.S.S.R., August 1967.

Sangal, B.P. and Biswas, A.K., "The 3-Parameter Lognormal Distribution and Its Applications in Hydrology", Water Resources Research, Vol. 6 No. 2, April 1970.

Past Applications: Southern Ontario Flood Study

Input: Number of years of record
Drainage area
Annual peak flows

Output: Drainage area
Mean, standard deviation, coefficient of variation, and coefficient of skew of the annual peaks, log base 10 annual peaks and log base 10 of annual peaks minus a parameter A
Median of peak flows
Parameter A
Flood estimates using the Gumbel, Pearson III, Log-Pearson III, Log-Normal and 3-Parameter Lognormal distribution for given probabilities and return periods
Floods ranked in descending order with their cumulative probability

Comments: Other programs are currently being considered to calculate flood frequencies for the Pearson III and 3-Parameter Lognormal distributions by the method of maximum likelihood.

Recommendations: This is the recommended program for calculating flood frequencies.

FLDFRQ

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program documentation (November, 1972)

Available From: Engineering and Econometric Systems Section, Water Management Systems Division or Engineering Hydrology Section, Engineering Division

Author: D. Cuthbert and G. Latham, Engineering Systems Section

Purpose/Technique: The flood frequency regimes of given rivers are estimated using the Gumbel I distribution. Distribution parameters are estimated by the method of maximum likelihood, and the frequency regimes are computed from the cumulative probability function.

Reference: Panchang, G.M., "Improved Precision of Future High Floods", paper presented at the International Symposium on Floods and their Computation, Leningrad, U.S.S.R., August 1967.

Input: Flood magnitudes

Output: Station analyzed
Period of historic record
Drainage area
Floods for 2.33, 5.0, 10.0, 20.0 and 50 year return periods
Standard error
Confidence limits

Comments: The program has been revised since the documentation was written but the differences are minor. Larger return periods can easily be incorporated.

Recommendations: Program FRQAN is the recommended program. Program FLDFRQ could be used if a flood frequency analysis was required using only the Gumbel I distribution.

FLOOD

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program documentation (July, 1971)

Available From: Engineering and Econometric Systems Section, Water Management Systems Division or Engineering Hydrology Section, Engineering Division

Author: C.E. Bowers, A.F. Pabst and S.P. Larson; Department of Civil Engineering and Hydraulics, University of Minnesota

Purpose/Technique: The flood frequency regimes of given rivers are estimated using the Log-Pearson III distribution. Distribution parameters are estimated by the method of moments. The frequency regimes are then estimated using a stored frequency factor.

Reference: Bowers, C.E., A.F. Pabst and S.P. Larson. "Computer Program for Statistical Analysis of Annual Flood Data by the Log-Pearson Type III Method." Bulletin No. 39, Water Resources Research Centre, University of Minnesota, Graduate School, Minneapolis, Minnesota, July 1971.

Input: Flood magnitudes with optional estimated skewness

Output: All input data, with floods ranked in descending order
Magnitude of floods corresponding to recurrence intervals of 200, 100, 50, 25, 10, 5, 2, 1.25, 1.1111, 1.0526 and 1.0101 years for sample skewness, zero skewness and estimated skewness
Recurrence intervals and probabilities; mean, standard deviation, and skewness of the floods; logarithms of the floods; mean, standard deviation, and skewness of their logarithms

Comments: Program FRQAN uses this and several other frequency distributions. The portion of program FRQAN which uses the Log-Pearson III distribution computes, rather than stores, a frequency factor and FRQAN is in this respect superior.

Recommendations: Program FRQAN is the recommended program. Program FLOOD could be used if a flood frequency analysis was required using only the Log-Pearson III distribution. FLOOD could be improved by computing, rather than storing, the frequency factors.

LOW FLOW ANALYSIS

LOFLOW

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program listing with sample output

Available From: Engineering Hydrology Section, Engineering Division

Author: G.A. Nix and L.G. Boone, Engineering Hydrology Section

Purpose/Technique: Computation of low flow frequency curves using the Gumbel III distribution. Distribution parameters are estimated by the first of the following methods to produce an acceptable result:

a) Method of smallest observed drought,
b) Method of maximum likelihood,
c) Method of moments.

References: Gumbel, E.J., "Statistics of Extremes". Columbia University Press, New York, 1958.

Gumbel, E.J., "Statistical Forecast of Droughts". Bull. Int. Ass. Sci. Hydrol., 8(1), 5, 1963.

Condie, R. and Nix, G.A., "Low Flow Frequency Distributions and Parameters Estimation". Unpublished report, Engineering Division, in preparation.

Past Applications: Canada wide Low Flow Study

Input: Historical annual low flows

Output: Input data statistics
Distribution parameters
Low flow frequency curve (optional plot)

Comments: This program was developed during a study of low flow frequency distributions conducted by the Engineering Hydrology Section, Engineering Division. Acceptable results were obtained for 127 out of 130 selected Canadian data sets.

Recommendations: This is the recommended program for a low flow frequency analysis.

LOGNOR

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program listing

Available From: Engineering Hydrology Section, Engineering Division

Author: Unknown

Purpose/Technique: Performs a low flow frequency analysis using the Log-Normal distribution. By inserting an optional statement, M = (N + 2)/2 (as indicated in the listing), to reduce the number of data samples to half, the program will fit a curve to the lower half of the data only. The fitting is apparently performed by some combination of moments and frequency factors.

Input: Lowest flow for a given month for the period of record

Output: Input data ranked in ascending order
Mean, standard deviation, coefficient of skew
User specified return periods and corresponding low flow estimates
Standard error of estimate
Coefficient of correlation

Comments: It should be noted that for zero skewness the Log-Pearson Type III distribution reduces to the Log-Normal distribution. The internal documentation of the program is very poor and the analysis technique difficult to identify.

Recommendations: Program LOFLOW is the recommended program.

DURATION ANALYSIS

TEST

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program listing with sample output

Available From: Engineering and Econometric Systems Section, Water Management Systems Division

Author: M. Sydor, Engineering and Econometric Systems Section

Purpose/Technique: To produce a duration analysis for daily or monthly flows or elevations.

Past Applications: Roseau River

Input: Daily or monthly flows or elevations

Output: A duration analysis table (percentage of time the specified flow or elevation is equalled or exceeded) with the option of having the analysis plotted.

Comments: This program has a great deal of flexibility and when documented should replace programs SOURIS and DATAN.

Recommendations: Programs DATAN and SOURIS will have to be used until this program is documented or, time permitting, this program should be used and documented.

DATAN

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program documentation (January, 1973)

Available From: Engineering and Econometric Systems Section, Water Management Systems Division or Engineering Hydrology Section, Engineering Division

Author: G.L. Latham, Engineering and Econometric Systems Section

Purpose/Technique: To produce a monthly duration analysis.

Past Applications: Great Lakes
Souris River

Input: Monthly discharges or elevations

Output: Annual mean
Long-term monthly means
Standard deviations (monthly)
Coefficients of variation and skew (monthly)
Maximum and minimum values for the period of record with occurrence date
Duration analysis - for each month, for specified elevations, the percentage of time the specified elevation is equalled or exceeded

Comments: Although this program is written to analyze Great Lakes data it is easily modified. The program does not include a plot routine.

Recommendations: The recommended program for a monthly duration analysis until such time as TEST is documented.

SOURIS

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program documentation (August, 1974)

Available From: Engineering and Econometric Systems Section, Water Management Systems Division, or Engineering Hydrology Section, Engineering Division

Author: J. Brydges, Engineering and Econometric Systems Section

Purpose/Technique: To produce a daily duration analysis.

References: Souris River Hydrology Report - The Garrison Diversion and its Effect on Flooding in Canada. Internal report by the Engineering Division dated August 1974.

Past Applications: Souris River

Input: Daily discharges or elevations

Output: Duration Analysis:
For the period of record, for each month; the number of days that a specified discharge is exceeded and the number of 1 day, 5 day, 10 day, 50 day, 100 day and 200 day floods which commenced in that month.

Comments: The method for converting this program to apply to another river is not elaborated in the documentation, but notes have been made on a program listing of those items which specifically applied to the Souris River. It would not be difficult to convert this program for use elsewhere.

Recommendations: The recommended program for a daily duration analysis until such time as TEST is documented.

BACKWATER CALCULATIONS

BWATER

Computer Language: Fortran IV

Computer: CDC 6400 (tape), GE-427 (cards)

Documentation: Program documentation (November, 1973)

Available From: Engineering and Econometric Systems Section, Water Management Systems Division or Engineering Hydrology Section, Engineering Division

Author: Hydraulics Section, N.Y. District, U.S. Army Corps of Engineers

Purpose/Technique: Given channel cross sections and roughness coefficients the program computes additional hydraulic properties which are then used to compute water-surface elevations, cross-sectional areas and velocities under backwater conditions.

Past Applications: Richelieu-Champlain Study

Input: Cross section coordinates
Roughness between each pair of coordinates
Pertinent data for special structures such as bridges and dams
Starting elevations
Desired discharges
Certain condition setting and control constants

Output: For each channel cross section and specified elevations:
- Area
- Roughness coefficient
- Velocity correction coefficient
- Hydraulic radius
- Top width
- Effective roughness

For each station:
- Water-surface elevation
- Energy gradient elevation
- Area
- Velocity
- Velocity head
- Friction slope
- Friction headloss
- Headloss due to either an expansion or contraction

Comments: The card deck on hand is as obtained from the U.S. Corps of Engineers. A CDC 6400 version is on tape. The program listing indicates the changes made to the program for use on the CDC 6400, as well as a correction to the program. These changes are explained in the program documentation.

Recommendations: The recommended program for backwater calculations.

BACKWAT

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program listing with sample output

Available From: Engineering Planning and Design Section, Engineering Division

Author: T. Tung, Engineering Planning and Design Section

Purpose/Technique: Computes water surface profiles for natural rivers and open channels using the standard step method.

References: Flood Risk Maps In The St. John River Basin New Brunswick. Internal Report, Engineering Planning and Design Section, Engineering Division, Water Planning and Management Branch, Environment Canada, June 1974.

Past Applications: St. John River Basin

Input: Manning's roughness coefficients for the main channel and the berm channel
Cross section data, including bridges and piers
Water level at the first downstream cross-section
Design discharge (mean of extreme values)

Output: For each section of the reach:
Manning's roughness coefficients
Cross section areas
Calculated flood velocity
Total head (stage plus velocity)

Comments: A flow chart and pertinent equations for the program are given in the above mentioned reference. The program is similar to BWATER but not as complex.

Recommendations: Program BWATER is the recommended program as it has been more widely used and tested. BACKWAT is simpler and provides satisfactory results.

CULVERT

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program documentation (August, 1974)

Available From: Engineering Planning and Design Section, Engineering Division

Author: T. Tung, Engineering Planning and Design Section

Purpose/Technique: Checks the hydraulic design of culverts. With the culvert cross section, slope, length and design flow given, the program provides information with respect to the flow profile.

Past Applications: Mackenzie Highway Study

Input: Culvert upstream and downstream elevations
Culvert dimensions
Manning's roughness coefficient
Entrance loss coefficient
Discharge and corresponding tailwater elevation

Output: Whether culvert outlet is submerged or unsubmerged
Whether there is full flow or part full flow
Critical depth and normal depth for the flow
Whether culvert is on mild, steep or critical slope
Type of flow (subcritical, supercritical or critical)
Water surface profile in the culvert
Depth and velocity at the control section and entrance
Total head and freeboard at entrance

Comments: The documentation is well illustrated.

Recommendations: This is the recommended program for checking the hydraulic design of culverts.

STREAMFLOW ROUTING

A. Analytical or Approximate Solutions

SSARR

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program documentation (September, 1972)

Available From: Engineering Hydrology Section, Engineering Division

Author: U.S. Army, Corps of Engineers

Purpose/Technique: The model was designed for operational use in the planning, design, and operation of water control works; operational river forecasting, and river management. Routing through the watershed, river system, and reservoir components of the model is based on the storage equation. Only the river system and reservoir components of the model are treated here.

References: U.S. Army. 1972. Program description and user manual for SSARR model. Program 724-K5-G0010.

Water Survey of Canada/Atmospheric Environment Service. 1972. Phase I report to the P.P.W.B. on Streamflow Forecasting.

Past Applications: Columbia River
Mekong River
St. John River
South Saskatchewan River
Ottawa River

Input: Recorded discharges, elevations and storages
Reservoir regulation policies
Routing parameters
Upper and lower bounds on reservoir elevations

Output: Discharge and elevation values at specified time intervals in the form of tabulations and plots

Comments: The watershed portion of the model requires a meteorological data base. Reservoirs can be simulated under (a) freeflow, (b) outflow, (c) pool elevation or changes in elevation, and (d) storage or changes in storage. The model is extremely flexible, well documented, and achieves a sound balance between hydrologic theory and practical considerations related to daily operational use.

Recommendation: The recommended model for the study of a highly regulated river system which does not require the use of a watershed submodel. Judgement on the watershed submodel of the SSARR is withheld pending further review and investigation.

PAD

Program Language: Fortran IV

Computer: IBM 360/70

Documentation: Program listing with sample output

Available From: Engineering and Econometric Systems Section, Water Management Systems Division

Author: Hydrology Branch, Alberta Environment

Purpose/Technique: Determines Lake Athabasca stages, and flow conditions in the network system: Riviere des Rochers, Chenal de Quatre Fourches, Revillon Coupe and the reach of the Peace River between the Quatre Fourches and Rochers channels; both under existing conditions and with various proposed control structures. This involves solving a simple (approximate) open channel flow equation, the continuity equations at the channel confluences, and the stage/volume and water balance equations for Lake Athabasca by an iterative technique referred to as "bootstrapping".

References: Hydrological Investigations. The Peace-Athabasca Delta Project, Technical Appendices, Vol. 1, 1973. Prepared by the Peace-Athabasca Delta Project Group; Canada, Alberta, Saskatchewan.

Past Applications: Peace-Athabasca Delta Study

Input: Daily recorded water elevation on Lake Athabasca at Fort Chipewyan and at Crackingstone Point
Daily recorded flow for Peace River at Peace Point, Slave River at Fitzgerald, Athabasca River at McMurray, Fond-du-Lac River at Black Lake, and Peace River at Hudson Hope
Precipitation and evaporation data for Lake Athabasca

Output: Lake Athabasca stages, and flow conditions in the various channels linking Lake Athabasca and the Peace River; either under existing conditions or with various proposed structures

Comments: This is an area specific program which would have to be rewritten for other areas. Presently, work is being undertaken by the Engineering and Econometric Systems Section to improve the program by considering Fort Chipewyan as a separate unit instead of part of Lake Athabasca. More extensive modifications might necessitate the replacement of the "bootstrapping" technique by a more sophisticated technique for solving systems of non-linear equations.

Recommendations: Recommended as an example of a system specific streamflow simulation using an approximate routing equation.

CYPRESS

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program documentation (March, 1974)

Available From: Engineering Hydrology Section, Engineering Division

Author: D.R. Cuthbert, Engineering Planning and Design Section

Purpose/Technique: Calculation of natural outflow volumes from the Cypress Lake Reservoir and interbasin water transfer between the Frenchman River and Battle Creek using the water balance equation: channel input + local inflow = channel output + seepage loss + evaporation ± change in storage.

References: D.R. Cuthbert, and E.R. Langley. March, 1974. Frenchman River Hydrology Study. Water Planning and Management Branch, Environment Canada.

Input: Regulated flows and storages
Irrigation volumes
Evaporation rate

Output: Ten-day total natural outflows and evaporation from the Cypress Lake Reservoir.

Comments: This is an area specific program which provides input to programs FRENCH and RIVER (see pages 36 and 37).

Recommendations: See programs FRENCH and RIVER.

FRENCH

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program documentation (March, 1974)

Available From: Engineering Hydrology Section, Engineering Division

Author: D.R. Cuthbert, Engineering Planning and Design Section

Purpose/Technique: Calculation of ten-day total natural flows in the Frenchman River for the period 1951-1970 inclusive using the water balance equation: channel input + local inflow = channel output + seepage loss + evaporation.

References: D.R. Cuthbert, and E.R. Langley. March, 1974. Frenchman River Hydrology Study. Water Planning and Management Branch, Environment Canada.

Input: Reach lengths
Drainage areas
Regulated flows and storages
Irrigation volumes
Evaporation rate
Estimated natural outflows from Cypress Lake Reservoir as output from program CYPRESS

Output: Ten-day total natural flows for selected locations.

Comments: This is an area specific program which would have to be rewritten for other drainage basins. Under agreement with Environment Saskatchewan the distribution of this program is restricted. Program FRENCH provides input to program RIVER.

Recommendations: Recommended as an example of natural flow calculations using the water balance equation.

RIVER

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program documentation (March, 1974)

Available From: Engineering Hydrology Section, Engineering Division

Author: E.R. Langley, Engineering Hydrology Section

Purpose/Technique: Simulation of regulated streamflow and available water supply along the Frenchman River under various operating policies using the water balance equation: channel input + local inflow = channel output + seepage loss + evaporation ± change in storage.

References: D.R. Cuthbert, and E.R. Langley. March, 1974. Frenchman River Hydrology Study. Water Planning and Management Branch, Environment Canada.

Input: Reach lengths
Natural flows as output from programs CYPRESS and FRENCH
Regulated reservoir elevations
Irrigation volumes
Evaporation rate
Natural evaporation losses from the Cypress Lake Reservoir as output from program CYPRESS

Output: Reach lengths
Natural flows, as above
Reservoir operation data
Irrigation volumes
Simulated flows
Available water supply
Seepage and evaporation losses

Comments: This is an area specific program which would have to be rewritten for other drainage basins. Under agreement with Environment Saskatchewan the distribution of this program is restricted. Separate documentation is available for programs CYPRESS, FRENCH and RIVER.

Recommendations: Recommended as an example of streamflow simulation and reservoir regulation using the water balance equation.

STREAMFLOW ROUTING

B. Numerical Solutions

STLR

Program Language: Fortran G

Computer: IBM 360

Documentation: Program documentation (March, 1974)

Available From: Engineering and Econometric Systems Section, Water Management Systems Division

Author: Surveyor, Nenniger & Chênevert Inc., Montreal, Quebec and Carrier, Trottier, Aubin, Consultants, Quebec, and Environment Canada, Ministry of Transport, Quebec Water Board and Quebec Department of Natural Resources

Purpose/Technique: Originally written to predict the effect of man made changes in the regime of the St. Lawrence River, this transient hydrodynamic and water quality model simulates flow and water quality on a time - varying or steady state basis. It consists of an implicit finite - difference solution of the general partial differential equations of motion and of mass transport, dispersion and decay. Only the hydrodynamic portion of the model is considered here. The one dimensional solution permits branching lines of nodes and hence becomes a pseudo-two dimensional solution.

References: Hydrodynamic Simulation Models for the St. Lawrence River. Proposal to the Department of the Environment for the development of same by Surveyor, Nenniger and Chênevert Inc., Montreal, Quebec, August 1972.

Hydrodynamic and Water Quality Simulation Model, Study of Saint-Lawrence River, Cornwall-Varennes Section. Surveyor, Nenniger & Chênevert Inc., Carrier, Trottier, Aubin Consultants, March 1973. See also Appendix B.

Chakrabarti, T.K. and A.S. Aggarwal. August 1974. Roseau River - Application of St. Lawrence River Model. Water Management Systems Division, Water Planning and Management Branch.

Past Applications: St. Lawrence River Study

Input: For the hydrodynamic model:
Cross section data
Reach geometry parameters (length, slope)
Node locations and other nodal details
Location of gauging stations and rating curves
Manning's roughness coefficients
Boundary conditions
Initial conditions
Lateral inflows

Output: For the hydrodynamic model:
Hydraulic description of the reaches
Lateral inflow hydrographs
Hydraulic description of nodes
Hydrographs of elevation, depth, discharge and velocity
Hydraulic profiles of elevation, depth, discharge and velocity

(CONTINUED)

STLR (Continued from p. 39)

Comments: The updated version (March 1974) of the second reference given above is only available in French. The hydrodynamic model has been successfully applied to the Roseau River.

Recommendations: Only the hydrodynamic model is considered here. Program STLR is the recommended numerical routing technique because (1) it is an implicit scheme and hence can accomodate larger time steps than an explicit scheme and (2) the option for branching lines of nodes gives the model a two dimensional capability. Program SOCH uses an explicit scheme and does not permit branching lines of nodes. However, program SOCH should be easier, and hence faster, to apply than STLR and thus may be the most suitable program for simpler problems.

SOCH

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program documentation (no date)

Available From: Engineering and Econometric Systems Section, Water Management Systems Division, or Engineering Hydrology Section, Engineering Division

Author: Tennessee Valley Authority

Purpose/Technique: Computes stage, discharge and velocity at predetermined intervals of time and space throughout a reservoir or river channel using an explicit finite difference solution of the continuity and momentum equations.

References: Nicomekl-Serpentine River Flood Control Study, Part II - Upstream Section, Preliminary Design and Cost Estimate. Internal report by the Project Design and Appraisal Section, Engineering Division, Water Planning and Operations Branch, Environment Canada, June 1972.

Draper, D.W. 1973. Roseau River Hydrologic Modelling. Report prepared for the International Roseau River Engineering Board by the Water Planning and Management Branch, Environment Canada.

Past Applications: Nicomekl-Serpentine Study
Roseau River

Input: Channel cross sections
Initial conditions
Local inflows
Roughness factors
Boundary conditions
Reach lengths

Output: Input data
Stage, discharge and velocity at selected time intervals and locations

Comments: The plot routine described in the documentation is unavailable. This program has been examined by the U.S. Army Corps of Engineers and a copy of their documentation is on file which describes the equations and numerical procedure in greater detail than the TVA documentation. However, the program on hand is the TVA version and the TVA documentation should be consulted for running the program.

Recommendations: Recommended for consideration in detailed flow routing studies where reliable roughness estimates and channel cross sections are available. Should be compared with program UFLOW.

UFLOW

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program listing with sample output

Available From: Engineering Hydrology Section, Engineering Division

Author: R. Adamcyk, Engineering Hydrology Section

Purpose/Technique: Performs an unsteady flow routing using the method of characteristics.

Input: Channel dimensions
Initial steady state conditions
Local inflows
Manning's n
Boundary conditions

Output: Input data
Steady state depth and velocity starting at the downstream end
Unsteady depth, velocity and discharge starting at the upstream end
Summary

Comments: This program is shorter but not as well documented as SOCH.

Recommendations: Recommended for consideration in detailed flow routing studies. Should be compared with program SOCH.

STREAMFLOW ROUTING

C. Empirical Techniques

MACK

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program listing with sample output

Available From: Engineering Hydrology Section, Engineering Division

Author: R. Adamcyk, Engineering Hydrology Section

Purpose/Technique: To determine the hydrologic effects of diversions within the headwaters area of the Mackenzie Basin, the program routes monthly flows through the basin using channel lag times in a simple attenuation equation.

References: The Effects of Southward Diversion on the Athabasca-Mackenzie Basin. Unpublished report by the Engineering Division, Water Planning and Operations Branch, Environment Canada for the Saskatchewan-Nelson Basin Board, September 1971. See also Appendix A, bound separately.

Input: Monthly historic streamflow

Output: Monthly regulated flows and stages

Comments: The program is poorly documented. See page 31 of the above report for the routing equation.

Recommendations: The method is appropriate for obtaining rough estimates for large river systems. Future studies of the Mackenzie Basin will probably necessitate the development of a more accurate method; with larger, yet feasible, computer time requirements.

UNIT HYDROGRAPH TECHNIQUES

UGRAPH

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program listing with sample output

Available From: Engineering Hydrology Section, Engineering Division

Author: Unknown

Purpose/Technique: Unit hydrograph determination from a single flood by least squares curve fitting.

References: Computer - Determined Unit Hydrograph from Floods. D.W. Newton, and J.W. Vinyard. ASCE, Journal of the Hydraulics Division, Vol. 93, HY5, pp. 219-235, September 1967.

Input: Basin area
Number of hydrograph ordinates
Number of units of precipitation excess
Time interval
Hydrograph ordinates (cfs)
Precipitation excess

Output: Hydrograph ordinates in cfs
Hydrograph ordinates in inches
Cumulative hydrograph ordinates in inches
Precipitation excess
Unit hydrograph ordinates

Comments: Past experience indicates that UGRAPH gives more reliable results than UNITGH.

Recommendations: The recommended general purpose unit hydrograph technique.

UHGOPT

Program Language: Fortran IV

Computer: IBM 1620

Documentation: Program Documentation (August, 1966)

Available From: Engineering Hydrology Section, Engineering Division

Author: U.S. Army Corps of Engineers

Purpose/Technique: To determine the best fit unit hydrograph and loss coefficients according to a least squares criterion.

References: "Unit hydrograph and loss rate optimization". Hydrologic Engineering Center, U.S. Army Corps of Engineers, August 1966.

Input: Hydrograph ordinates
Number of hydrographs
Drainage area
Rainfall interval
Clark's coefficients
Number of precipitation periods in storm
Starting values for loss amounts and loss coefficients
Time-area table
Impervious area
Rain and snow melt

Output: Input, except time-area table
Standard error for each flood at each iteration
All changes in input data and each variable change
Optimised variables and coefficients
Unit hydrograph tabulation
Summary tabulation of rain, loss, excess, recession, computed flow and observed flow

Comments: An artificial time-area tabulation in the program can be used if desired. The loss rate variables can be specified and held constant in order to simplify the analysis, but probably at the expense of less accurate results. While it is advantageous to suggest approximate values for variables to begin each analysis, the program will initiate any or all of them, if not supplied. It is best to supply at least an initial estimate of time of concentration.

Recommendations: This program has not been tested and since it is more complex than UGRAPH cannot be recommended for general use. It should be further examined at the next opportunity. The program can probably be constrained to yield results similar to those of UGRAPH and further familiarity with the program would permit use of its additional features if, as and when required.

UNITGH

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program documentation (September, 1967)

Available From: Engineering Hydrology Section, Engineering Division

Author: Tennessee Valley Authority

Purpose/Technique: Computes a unit hydrograph from a single flood or a best fit (composite) unit hydrograph from several floods. In addition, by an iterative fitting procedure, it will modify the given time distribution of precipitation excess giving an improved estimate of the distribution.

References: Computer-Determined Unit Hydrograph from Floods. D.W. Newton, and J.W. Winyard. ASCE, Journal of the Hydraulics Division, Vol. 93, HY5, pp. 219-235, September 1967.

Computer Program for Unit Graph Determinations. Tennessee Valley Authority, Knoxville, Tennessee, September 1967.

Input: Number of floods
Drainage area
Number of rainfall excess ordinates
Number of flood ordinates
Error criterion
Flood ordinates
Rainfall ordinates
Rainfall excess ordinates
Time interval

Output: Input data
Interim calculations
Number of iterations
Error
Final unit hydrograph ordinates
Modified precipitation excess

Comments: This program was examined during the Nicomekl-Serpentine study and abandoned in favour of UGRAPH. It should be noted that UGRAPH is based on the same technique as UNITGH but is a simpler program which analyzes one flood at a time.

Recommendations: Recommended for further investigation at the next opportunity.

GRAPHA

Program Language: Fortran IV

Computer: UNIVAC 1108

Documentation: Program documentation (no date)

Available From: Engineering Hydrology Section, Engineering Division

Author: E.R. Langley, Engineering Hydrology Section

Purpose/Technique: Calculates unit hydrographs for ungauged areas using area-time histograms.

References: D. Johnstone and W.P. Cross. Elements of Applied Hydrology. The Ronald Press Company, New York, 1949.

Input: Number of watersheds
K - Clark's constant, used for calculating C_1 and C_2 in the Muskingum equation
Area - time histogram

Output: Instantaneous unitgraph
1, 2, 3, ... 48 hour unit hydrographs, as specified
Constants for the Muskingum equation (C_1 and C_2)

Comments: The program was tested on Nova Scotia streams and yielded satisfactory results for short duration unitgraphs.

Recommendations: In lieu of a comprehensive regional unitgraph study to determine synthetic unitgraph parameters, this is the recommended technique for obtaining short duration unitgraphs for ungauged basins. An approach for determing regional unitgraph parameters is given by R.J. Adamcyk and E. Langley in their internal report "Estimating Storm Runoff Distributions on Ungauged Streams in Nova Scotia", Engineering Hydrology Section, Water Planning and Operations Branch, Environment Canada, July 1971. It should be noted that GRAPHA is not described in this study report but rather a regression technique which yielded satisfactory results for both long and short durations.

SYNTHETIC STREAMFLOW GENERATION

MUSH

Program Language: Fortran IV

Computer: IBM 360/85

Documentation: Program documentation (1972)

Available From: Engineering and Econometric Systems Section, Water Management Systems Division

Author: Engineering Division, Inland Waters Branch

Purpose/Technique: To generate monthly synthetic streamflow sequences for up to twenty-two stations, based on the historical flow record at each of the sites. A multisite, multiseason, lag-one Markov model is employed which preserves the interrelationship between flows at different sites, as well as the relevant statistical characteristics at each station.

References: G.K. Young, and W.C. Pisano. Operational Hydrology Using Residuals. Proceedings of the A.S.C.E., Hydraulics Division, pp. 909-923, July 1968.

Streamflow Synthesis Studies for the Fraser River Basin. Engineering Division, Water Planning and Operations Branch, Environment Canada, 1972.

Past Applications: Saskatchewan - Nelson basin study
Fraser River basin study

Input: Number of years of record
Number of seasons per year
Number of stations
Number of years of record to be generated
Historic mean monthly flows

Output: Interim skew calculations
Historic flows
Transformed flows (square root and log)
Matrices for the generation equation
Synthesized flows
Grand mean, standard deviation and skew coefficient
Monthly mean, standard deviation and skew coefficient

Comments: This program was selected over SNBBS for use on the Fraser River. Monthly flows as synthesized by MUSH can be input to DAGEN to synthesize daily flows (p. 51).

Recommendations: The recommended monthly flow generator.

DAGEN

Program Language: Fortran IV

Computer: IBM 360

Documentation: Program documentation (1972)

Available From: Engineering and Econometric Systems Section, Water Management Systems Division

Author: D.R. Cuthbert, Engineering Systems Section

Purpose/Technique: Generates daily streamflow based on Beard's regression method extended to multiple site. The required statistical parameters are calculated and punched on cards by DATEST (p. 4).

References: L.R. Beard. Simulation of Daily Streamflow. International Hydrology Symposium, Fort Collins Colorado, p. 624-632, September 1967.

Streamflow Synthesis Studies for the Fraser River Basin. Engineering Division, Water Planning and Operations Branch, Environment Canada, 1972.

D.R. Cuthbert. 1969. Development of a Daily Operational Hydrology Generator for use in Mathematical Modelling of Watershed Systems. M.A.Sc. Thesis, University of Waterloo.

Input: Output from DATEST
Output from monthly generator i.e. MUSH

Output: Selected input data
Synthetic daily streamflows

Comments: It should be realized that program DATEST was specifically written for use with DAGEN and that monthly flows have to be generated by another program (i.e. MUSH) for conversion by DAGEN into synthetic daily flows.

Recommendations: The recommended daily flow generator.

GENER

Program Language: Fortran IV

Computer: CDC 6400

Documentation: Program documentation (May, 1974)

Available From: Engineering and Econometric Systems Section, Water Management Systems Division

Author: M. Sydor, Engineering and Econometric Systems Section

Purpose/Technique: Computes the monthly basin supply for Lake Champlain (NBS = P + R + U - E where P = precipitation on the lake surface, R = runoff to the lake, U = groundwater inflow to the lake, and E = evaporation from the lake surface) for the period of record. The values of NBS are calculated using the water balance equation: NBS = O - I ± ΔS where O = outflow from the lake through its natural outlet, I = inflow from an upstream source and ΔS = change in the amount of water stored in the lake. The program then uses a lag-one Markov model to generate ten one-hundred year series of monthly basin supplies for Lake Champlain.

References: Lake Champlain-Richelieu River Synthetic Series. Report prepared by M. Sydor of Environment Canada under the direction of the Hydraulics Committee, International Richelieu-Champlain Engineering Board, Ottawa, February 1974.

Input: Monthly mean discharges
Stage storage equations

Output: Input
Historic and generated net basin supplies punched on cards
Means of historical and generated monthly means, standard deviations, skews, and autocorrelations
Frequency analysis by method of maximum likelihood (See FLDFRQ)

Comments: The lag-one Markov model is discussed in the above reference.

Recommendations: Program MUSH is the recommended monthly streamflow generator.

SNBBS

Program Language: Fortran IV

Computer: UNIVAC 1108

Documentation: Program listing with sample output

Available From: Engineering and Econometric Systems Section, Water Management Systems Division

Author: Engineering Division, Inland Waters Branch

Purpose/Technique: Monthly streamflow generation for any number of years and for up to 15 stations - accepting as input up to 60 years of recorded flows which must be simultaneous at all stations. A regression of the current flow on the previous X_i flows, where i is a user specified integer from one to twelve, and other flow variables is used to generate the synthetic flows.

References: L.R. Beard. 1965. Use of Interrelated Records to Simulate Streamflow. Journal of the Hydraulics Division, Proceedings of the American Society of Civil Engineers, 91, p. 13-22.

Fraser River Basin Study, Monthly Streamflow Generation. An internal report describing early attempts to apply this program to the Fraser River, no author or date.

Input: Number of stations
Number of years of record to be generated
Number of lag months up to and including 12 months
Historic mean monthly flows

Output: Input, excluding historic flows
Interim and final regression coefficients
Synthetic flows

Comments: Program MUSH is recommended over program SNBBS because MUSH preserves the relevant statistical characteristics of the historic flows.

Recommendations: MUSH is the recommended monthly flow generator.

FILLIN

Program Language: Fortran IV

Computer: IBM 360/85

Documentation: Program documentation (no date)

Available From: Engineering and Econometric Systems Section, Water Management Systems Division or Engineering Hydrology Section, Engineering Division

Author: D.R. Cuthbert, Engineering Division

Purpose/Technique: To fill data voids in monthly flow data using a regression on available monthly flows and a random component.

References: G.K. Young, G.T. Orlob, and L.A. Roesner. 1969. Decision Criteria for Using Stochastic Hydrology. Paper presented at the A.S.C.E. Hydraulics Division Specialty Conference, Logan, Utah.

Past Applications: Battle Creek

Input: No of years of record
Mean monthly flows

Output: Historic mean monthly flows
Sorted flows
Monthly mean and standard deviations
Natural log transform statistics (mean, standard deviation, skewness, coefficient of variation)
Log base 10 transform statistics
Square root transform statistics
No transform statistics
Regression on rows of data matrix
Statistics using filled in data
List of data with all voids filled in

Comments: The technique used is similar to that in SNBBS. The technique in MUSH could be adapted to the same purpose.

Recommendations: This program is probably adequate for most purposes.